An optical neural interface: in vivo control of rodent motor cortex with integrated fiberoptic and optogenetic technology.

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Public Summary:

Scientific Abstract:
Neural interface technology has made enormous strides in recent years but stimulating electrodes remain incapable of reliably targeting specific cell types (e.g. excitatory or inhibitory neurons) within neural tissue. This obstacle has major scientific and clinical implications. For example, there is intense debate among physicians, neuroengineers and neuroscientists regarding the relevant cell types recruited during deep brain stimulation (DBS); moreover, many debilitating side effects of DBS likely result from lack of cell-type specificity. We describe here a novel optical neural interface technology that will allow neuroengineers to optically address specific cell types in vivo with millisecond temporal precision. Channelrhodopsin-2 (ChR2), an algal light-activated ion channel we developed for use in mammals, can give rise to safe, light-driven stimulation of CNS neurons on a timescale of milliseconds. Because ChR2 is genetically targetable, specific populations of neurons even sparsely embedded within intact circuitry can be stimulated with high temporal precision. Here we report the first in vivo behavioral demonstration of a functional optical neural interface (ONI) in intact animals, involving integrated fiberoptic and optogenetic technology. We developed a solid-state laser diode system that can be pulsed with millisecond precision, outputs 20 mW of power at 473 nm, and is coupled to a lightweight, flexible multimode optical fiber, approximately 200 microm in diameter. To capitalize on the unique advantages of this system, we specifically targeted ChR2 to excitatory cells in vivo with the CaMKIIalpha promoter. Under these conditions, the intensity of light exiting the fiber (approximately 380 mW mm(-2)) was sufficient to drive excitatory neurons in vivo and control motor cortex function with behavioral output in intact rodents. No exogenous chemical cofactor was needed at any point, a crucial finding for in vivo work in large mammals. Achieving modulation of behavior with optical control of neuronal subtypes may give rise to fundamental network-level insights complementary to what electrode methodologies have taught us, and the emerging optogenetic toolkit may find application across a broad range of neuroscience, neuroengineering and clinical questions.